Development of the Persistence in Engineering (PIE) Survey Instrument

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Abstract

This paper describes the design, development, and validation of the Persistence in Engineering (PIE) survey instrument. The purpose of the survey is to identify and characterize the fundamental factors that influence students' intentions to pursue an engineering degree over the course of their undergraduate career, and upon graduation, to practice engineering as a profession. The design of the survey entails development of conceptual variables and survey questions generated from a review of engineering education literature and national surveys on undergraduate education, piloting of the survey, and internal consistency analyses. Currently in its second year, the instrument is being administered with 160 students selected from four academic campuses.

In this paper, we present the variables that are guiding the design of the PIE survey, and discuss each variable in depth by providing its rationale. In addition, we discuss how the data collected during the first year–and-one-half of the study are being used to refine the survey instrument, including assessments of internal consistency of the variables. We also describe how data collected from an accompanying set of structured interviews are being used to inform the development of the instrument.

I. Introduction

The Academic Pathways Study (APS) of the Center for the Advancement of Engineering Education (CAEE) is building upon knowledge related to retention in engineering education by employing quantitative and qualitative approaches to establish a longitudinal research base on engineering student learning. This paper focuses on the Persistence in Engineering (PIE) survey instrument developed as a part of the APS.

A. Background

While engineering educators have engaged in many endeavors aimed at advancing engineering education and practice, much of this work has focused on broad curricular issues or specific disciplinary reforms. Few studies have focused on the many pathways involved in learning to engineer [1,2]. The APS aims to accelerate recent efforts directed toward the development of a research base on engineering student learning. This section summarizes some of the more influential studies contributing to that knowledge base.

Huang, Taddese, and Walter examined how gender and ethnicity relate to entrance, persistence, and attainment of postsecondary science and engineering education [3]. The data collected during two previous survey-based longitudinal studies, the National Educational Longitudinal Study of 1998 (NELS:88) and the Beginning Postsecondary Longitudinal Study (BPS) were analyzed. Starting in academic year 1988-89, NELS was conducted with eighth-graders through high school and into college or the workforce, and BPS, with college students starting their first college year (1989-90) to five years later (1993-94). The following factors were found to be significant for choosing to major in science and engineering, regardless of ethnicity or gender: enrollment in advanced science courses in high school, self-motivation to study science, parents with advanced degrees, and parents with high expectations for their child's education. Upon a student's decision to major in engineering, ethnicity and gender were found to be factors in degree completion.

Besterfield-Sacre, *et al* developed the Pittsburgh Freshman Engineering Attitudes Survey (PFEAS) in order to understand how "students' initial attitudes about engineering and their abilities" may relate to attrition in engineering [4,5,6]. Data collected at a single institution showed that students' attitudes may change significantly during their first college year. Positive shifts in the attitudes towards "working in groups" and the perception of engineering as a "precise" science were likely. Using the PFEAS and demographic data, students who left engineering were differentiated into two categories: students who left engineering in good academic standing as compared to those who left in poor academic standing. The analysis revealed that students who left engineering in good academic standing reported lower attitudes on a variety of measures related to their impressions of engineering and confidence in engineering and science skills. In contrast, students who left in poor academic standing had more "positive" attitudes towards engineering and their abilities compared to students who either stayed in engineering or those who left in good academic standing.

Brainard, *et al*, administered a survey to a cross-sectional population of more than 8,000 freshman to senior engineering students at 29 different institutions in order to assess engineering student perceptions of the educational climate [7]. Male students consistently reported higher self-confidence in academic measures, as well as confidence that engineering was the "right major," while female students reported being more "overwhelmed by the fast pace and heavy workload" of majoring in engineering. Most academic confidence measures were the lowest during freshman year and peaked during senior year, but some measures did not follow this trend. This finding suggests the need for a longitudinal analysis of engineering students' perceptions and skills to capture the changes.

In the *Women and Men of the Engineering Path* study, Adelman used the data from the 11-year college transcript history from the High School and Beyond/Sophomore Cohort Longitudinal Study (1982-93) and responses to the Cooperative Institutional Research Program Survey in order to track the academic progress of engineering students in college [8]. The women who left engineering were found to have earned higher grades than the men who left, although women and men earned similar grades in engineering courses. Furthermore, women who left engineering did not leave because of poor academic performance although they cited a higher degree of "academic dissatisfaction." The "perception of overload" was found to be a factor in students' decisions to leave engineering.

In their seminal work on persistence in science and engineering education, Seymour and Hewitt interviewed over 300 juniors and seniors at 7 institutions about their decisions to "switch out of" or stay in science, math and engineering majors [9,10]. The researchers found that there was "no single overwhelming concern for the decision to switch, rather students engaged in a process of reactions to problems with the science and engineering major, concern about career, and the merits of alternative majors." The decision to switch was rooted in the students' "concern about the future," as well as "structural or cultural" sources within the institution, and not solely the academic rigors of the science and engineering majors. Furthermore, students who stayed and those who switched out raised the same set of concerns about majoring in science and engineering.

This overview gives a glimpse into the substantive corpus related to issues of persistence in engineering. For the most part, these studies rely on either cross-sectional data or longitudinal data from national databases not necessarily targeted at engineering students. As Brainard's findings suggest, there is a need to conduct longitudinal research with engineering students in order to identify and track factors related to persistence in engineering. A detailed, time-sensitive knowledge base would inform the design of effective time-sensitive interventions in order to increase retention in engineering education.

B. Goal of the PIE Survey

The PIE Survey aims to identify salient correlates of persistence in engineering. The instrument identifies and explores two levels of persistence: academic and professional. "Academic persistence" is operationalized as declaring an intention to major in engineering, and "professional persistence" is operationalized as declaring an intention to practice engineering for at least three years after graduating with a bachelor's degree.

The PIE instrument is designed to generate knowledge about persistence factors to extend the research base on engineering student learning and retention. At the end of the APS, our main focus will be to disseminate the insights gained with the PIE instrument together with the validated version of the instrument so that interested engineering education researchers can leverage that knowledge to design meaningful interventions.

C. The Academic Pathways Study (APS)

The Academic Pathways Study is an element of the Center for the Advancement of Engineering Education (CAEE), an NSF-funded higher education Center for Learning and Teaching, which commenced in January 2003. The primary objective of the APS is to conduct research on the engineering learning experience in order to provide a comprehensive account of how people become engineers, thereby creating insights into key questions in engineering education [11]. The APS will facilitate better understanding of how engineering students navigate their education (successfully or unsuccessfully), explore how misalignments between university and workplace practices influence preparation and retention, and describe how students' learning and working environments intersect with engineering. The studies will help educators understand how engineering learning and educational experiences vary across populations and institutions, identifying significant factors related to gender, ethnic, and geographic diversity.

APS addresses the following fundamental research questions:

- SKILLS: How do students' engineering skills and knowledge develop and/or change over time? How do the technological and mathematical fluencies of engineering students compare with those found in professional engineering settings?
- IDENTITY: How do these students come to identify themselves as engineers? How do students' appreciation, confidence, and commitment to engineering change as they navigate their education? How does this in turn affect how these students make decisions about further participation in engineering after graduation?
- EDUCATION: What elements of students' engineering educations contribute to the changes observed in questions one and two? What do students find difficult and how do they deal with the difficulties they face?
- WORKPLACE: What skills do early-career engineers need as they enter the workplace? Where did they obtain these skills? Are there any missing skills? How are people's identities transformed in moving from school to work?

The APS consists of four cohorts. Cohort 1 is a longitudinal study of student participants at four academic institutions. The same individuals are being studied from their first through third years in college. Cohorts 2-4 extend the study to include additional students on the four campuses and at CAEE-affiliate institutions. The study uses three primary investigative tools: surveys, structured interviews, and ethnographic observations. Surveys and interviews provide data on a large set of participants, while ethnographies provide deeper information on a more limited number of subjects. Each tool provides a set of insights that informs the other tools, allowing generalization of specific findings to a broader population.

II. Survey Development Process

Development of the PIE survey is iterative, and its scope and contents are evolving. As each administration of the survey reveals new insights, the survey variables and items are evaluated and refined. During the first year and a half of Cohort 1, three surveys were administered, in January 2004, April 2004, and November 2004. The survey's most recent version is presented in the following section. During the remaining year and a half of Cohort 1, three more surveys will be administered. The insights gained from the series of Cohort 1 responses will be leveraged in adapting the resulting PIE instrument for administration with two broader and larger cross-sectional engineering student subject bases in Cohorts 3 and 4, which will yield more generalizable results.

Currently, the PIE Survey is exploratory and will rely on correlation analyses to identify relationships among the key variables associated with the fundamental APS research questions (categorized under skills, identity, education, and workplace in Section I) and academic and professional persistence in engineering.

The development of the PIE focuses on formulating and categorizing key research questions clustered around the concept of persistence in engineering. Most of these operational research questions were based on findings identified in our literature review on factors influencing retention in engineering. The operational research questions were then analyzed further, initially by the authors, and then by the greater APS community. Based on these discussions, several key variables were identified.

Existing national surveys focused on undergraduate education were also reviewed. Several variables directly related to the goals of the APS survey were identified and borrowed. The following national surveys were influential:

- Pittsburgh Freshman Engineering Attitudes Survey (PFEAS)
  http://www.engr.pitt.edu/~outcomes/#
- Cooperative Institutional Research Program Freshman Survey (CIRP)
  http://www.gseis.ucla.edu/heri/cirp_po.html
- Your First College Year 2003 survey
  http://www.gseis.ucla.edu/heri/yfcy/
- National Survey of Student Engagement
  http://www.indiana.edu/~nsse/
- College Student Experiences Questionnaire
  http://www.indiana.edu/~cseq/

Finally, our literature review discussions proved to be useful in identifying several new variables that had not been operationalized in the existing studies and surveys. These three processes yielded the PIE variables discussed in Section III. In order to measure each variable, a set of survey items were formulated and/or borrowed from the literature.

The PIE variables are being continuously refined after each administration of the survey. Reponses to each survey are being analyzed both qualitatively and quantitatively. Consideration of the responses has resulted in the refinement or deletion of existing variables, and the addition of new ones (a detailed discussion of the internal consistency analysis will be presented in Section IV).

In a parallel effort, a structured interview protocol was designed to explore variables that were more suited for qualitative analysis. The active nature of the interview data complemented the static nature of the survey data. The structured interview was aimed at:

1. Enriching survey data by adding depth and texture to the questions asked,
2. Filling existing gaps in the survey by asking additional questions not initially addressed
3. In achieving 1 and 2, providing feedback to be used in the refinement of the survey variables.

A structured interview schedule was employed as opposed to an informal interview schedule because comparable data were to be obtained across all four campuses. The use of questionnaire-driven interviews was advantageous in gaining detailed information on specific issues.

In order to create the structured interview protocol, each APS research question category was connected to its corresponding PIE variable(s). Then, the operationalization of each APS research question in the PIE Survey was specified, and used to examine potential gaps in the survey's attempt to answer the research questions.

The connections between APS research questions and the PIE variables were examined in order to highlight areas that needed more information and/or were not addressed by the PIE Survey. An extensive literature review was conducted to locate questionnaire instruments that could possibly be implemented in the interview protocol [11-16]. Additional interview questions were created as necessary. The resulting structured interview protocol was pilot tested with students in a psychology seminar at one of the campuses.

One of the main outcomes of the structured interviews will be to leverage the qualitative understanding we gain from the analysis to validate the relevance and refinement of the conceptualization of the survey variables.

III. Description of the PIE Survey Variables

Conceptually, each PIE Survey variable is associated with one of the four fundamental APS research question categories (see Section I-C for the categories). By measuring the variables over time and monitoring how they relate with persistence in engineering, the APS research questions under each category are being explored. The mapping of the PIE variables onto the APS research question categories is illustrated in Table 1 (PIE variables will be defined later in this section).

Table 1. *Mapping of the PIE variables onto the APS research question categories.*

APS Research Question Category	**Associated PIE Survey Variables**
SKILLS	4. Confidence in Engineering Knowledge and Skills 5. Perceived Importance of Engineering Knowledge & Skills 7. Ability to Solve Open-Ended Problems
IDENTITY	2. Motivation for Studying Engineering 3. Interpersonal Confidence 15. Extra-Curricular Fulfillment
EDUCATION	8. Opportunity to Solve Open-Ended Problems in Courses 9. Exposure to Project-Based Learning Methods 10. Interaction with Faculty 11. Interaction with Teaching Assistants 12. Satisfaction with Academic Facilities and Services 13. Overall Satisfaction with Collegiate Experience 14. Academic Disengagement 16. Curriculum Overload 17. Financial Difficulties 18. Personal Work Style 19. Work Style Promoted by the Institution
WORKPLACE	5. Perceived Importance of Engineering Knowledge & Skills 6. Knowledge of the Engineering Profession

Developmentally, the PIE variables can be grouped as follows (the process associated with the development of each category was described in Section II):

1. Variables that have been operationalized in existing surveys. Some of these variables were already operationalized in an engineering education or persistence in engineering context, and others were not. Variables 2a, 2b, and 2c and their items were borrowed from the PFEAS instrument. Variables 3, 10, 11, 12, and 14 and their items were borrowed from the FYFC instrument.
2. Variables that are known from the literature to be related to persistence in engineering, but have not been operationalized in a survey. These variables were identified mainly through qualitative methods such ethnographic studies or interviews. Variables 2d, 2e, 16, 17 are primarily based on Seymour's findings [9,10]. Variables 4 and 15 are primarily based on Austin's findings [17]. (Variable 4 is operationalized in the PFEAS instrument with a specific focus on technical engineering skills). Variables 7, 8, and 9 are primarily based on Dym's review [18].
3. Variables that are not based on the literature. Variables 5, 6, 18, and 19 are conceptualizations specific to the PIE Survey.

In synthesizing these three types of variables in a single instrument, the PIE Survey leverages existing instruments relevant to persistence in engineering, generates operationalizations of persistence factors that have been explored but not operationalized in a survey, and proposes conceptualizations of new persistence factors. Monitoring these variables over a period of three years within the APS for a specific student population will provide us with valuable longitudinal data.

Table 2 defines the PIE variables and provides rationale as to why they relate to persistence in engineering. It also provides references for the variables that have been based on existing study findings.

Table 2. *Definitions and rationale of the PIE Survey Variables.*

PIE Variable	**Variable Definition and Rationale**
1. Persistence in Engineering (Academic, Professional)	Level of persistence in engineering. This variable is defined at two levels: "Academic persistence" is an intention to *major* in engineering, whereas "professional persistence" is an intention to *practice* engineering for at least three years after graduating with a bachelor's degree. Although the second is contingent on the first, not all students who graduate with an engineering degree become professional engineers. Thus, the concepts are distinct and need to be measured separately.
2a.Motivation (Financial)	Motivation to study engineering due to the belief that engineering will provide a financially rewarding career. In Astin's study [17], engineering majors frequently reported that the "chief benefit of college is making money." Seymour found that the belief "science, mathematics and engineering career options and rewards are not worth the effort to get the degree" influenced the decision to leave engineering [9,10]. This variable was used in the PFEAS.
2b.Motivation (Family Influence)	Motivation to study engineering due to family influences. Astin found that having a father who is an engineer was an indicator for engineering as a career choice [17]. However, Seymour's findings suggest that men leaving

	science and engineering majors are those most likely to have followed a "family career tradition" into science and engineering fields [9,10]. This variable was used in the PFEAS.
2c.Motivation (Belief that Engineers Improve Social Welfare)	Motivation to study engineering due to the belief that engineers improve the welfare of society. Since Astin reported that the engineering majors frequently voiced the belief that "individuals can't change society" [17], it is relevant to investigate whether this motivation variable is a persistence factor. This variable was used in the PFEAS.
2d.Motivation (High School Teacher/Mentor Influence)	Motivation to study engineering due to influence of high-school teacher(s) and/or advisor(s). The Seymour study yielded qualitative findings indicating this motivation variable might be a persistence factor [9,10]. This variable was measured once during the initial year of Cohort 1.
2e.Motivation (Mentor Influence in College)	Motivation to study engineering due to the influence of mentor(s) while in college. This variable extends the rationale of 2e into the college years.
3. Interpersonal Confidence	Level of interpersonal confidence. The variable explores the relationship between self-efficacy and persistence in engineering education. Seymour identified "feeling discouraged/losing confidence due to low grades in early years" as a persistence factor [9,10].
4. Confidence in Engineering Knowledge & Skills (Technical, Professional)	Confidence in engineering knowledge and skills. Technical knowledge and skills refer to proficiency in science, critical thinking, real-world problem solving, and computation. Professional knowledge and skills refer to proficiency in business, communication and teamwork. Engineering majors frequently reported "growth in analytic and problem-solving skills" during their undergraduate careers in Astin's study [17]. Besterfield-Sacre also identified "low confidence in basic mathematics, science, and engineering skills" as a characteristic of engineering students who did not persist [4,5].
5. Perceived Importance of Engineering Knowledge & Skills (Tech., Professional)	Perceived importance of technical and professional engineering knowledge and skills, as measured by Variable 4, in becoming a successful engineer.
6. Knowledge of the Engineering Profession	Level of familiarity with the engineering profession. Familiarity is measured by the extent of interaction with professional engineers and/or exposure to professional engineering environments.
7. Ability to Solve Open-Ended Problems	Level of confidence in the ability to engage problems with multiple solutions. Although there is agreement that solving open-ended problems is what practicing engineers do, it is not clear whether engineering curricula successfully prepares students for the type of thinking required to tackle such problems [18].
8. Opportunity to Solve Open-Ended Problems in Courses	Level of opportunity to engage problems that have multiple solutions in coursework. Although there is agreement that solving open-ended problems is what practicing engineers do, it is not clear whether engineering curricula successfully exposes students to such problems [18].
9. Exposure to Project-Based Learning Methods	Level of exposure to project-based learning (PBL) pedagogies in courses. The majority of engineering students enjoy courses which utilize project-based learning methods [18]. Recent ABET requirements have resulted in an increase in design courses in engineering curricula, which are often taught using PBL.
10. Interaction with Faculty (Frequency, Satisfaction)	Frequency and level of satisfaction with interactions with faculty. High frequency of interaction accompanied by low levels of satisfaction might suggest poor teaching and advising; low frequency of interaction

	accompanied by low level of satisfaction might suggest lack of availability (engineering faculty often prioritize research over teaching). Seymour found "poor teaching by science, mathematics, and engineering faculty" to be a strong persistence factor [9,10].
11. Interaction with Teaching Assistants (Frequency, Satisfaction)	Frequency and level of satisfaction with interactions with teaching assistants. To carry out teaching responsibilities, engineering faculty often rely heavily on TAs, who might lack adequate teaching experience. This might be a persistence factor. Furthermore, a significant percentage of TAs in engineering are foreign students, and experience difficulties in classroom management and communication [9,10].
12. Satisfaction with Academic Facilities and Services	Level of satisfaction with academic facilities, such as classroom and laboratories, and services, such as academic advising. Since engineering is an applied science, satisfaction with academic facilities and services plays a critical role in persistence. Seymour identified inadequate advising; concerns with teaching, labs, or recitation support; and poor facilities as persistence factors [9,10]. Astin also found that engineering majors reported poor satisfaction with individual support services, such as career counseling, academic advising, and academic assistance [17].
13. Overall Satisfaction with Collegiate Experience	General satisfaction with the overall quality of the college experience. This question is asked at the end of the survey to obtain a Gestalt judgment response. This measure is thought to be closely related to Variable 1. Continued dissatisfaction with the overall college experience is hypothesized to result in low persistence.
14. Academic Disengagement (Non-Engineering Related, Engineering Related)	Frequency of events signaling disengagement from engineering and non-engineering courses. Seymour found that a lack of or loss of interest in science, mathematics and engineering, as well as a belief that non-engineering majors offer a "better education" were both persistence factors [9,10]. Thus, disengagement from engineering courses, while remaining engaged in non-engineering courses, might be a precursor to leaving engineering. On the other hand, disengagement from both engineering and non-engineering courses might be a precursor to leaving college.
15. Extra-Curricular Fulfillment	Desired vs. actual level of involvement in extra-curricular activities. In Astin's study, engineering majors reported low satisfaction with student life, including participation in extracurricular activities [17].
16. Curriculum Overload	Level of difficulty in coping with the pace and load demands of engineering-related courses. Seymour identified the level and the large volume of work required in the engineering curriculum, coupled with the rapid pace at which the information must be "absorbed," to be a strong persistence factor [9,10]. Adelman reported that although the engineering major "credit loads" are not significantly higher than those of other majors, engineering students "perceive overload because of the high ratio of classroom, laboratory, and study hours to credit awarded" [8].
17. Financial Difficulties	Level of comfort with obtaining financial support for studying engineering. Seymour found having difficulties with financing the engineering major to be a persistence factor [9,10].
18. Work Style (Personal-Collaborative, Competitive)	Preference for collaborative and competitive work. Collaborative and competitive work styles are taken to be orthogonal dimensions, meaning it is possible to indicate high preference for both. Since engineering education and practice require individuals to work in teams, students' preference toward collaborative work might prove to be a persistence factor. However,

	engineering education and practice also requires individuals to be competitive. Seymour found “morale being undermined by competitive” practices in the science, mathematics and engineering culture to be a persistence factor [9,10]. Thus, students’ preferences for competitive work might prove to be a persistence factor.
19. Work Style (Institution-Collaborative, Competitive)	Degree to which the institution promotes collaborative and competitive work. Potential mismatches between what the institution promotes and what the student prefers (for instance, a highly collaborative student who does not favor high competition enrolled in an institution which demands its students to be competitive) might prove to be a persistence factor.
Demographic Variables	Sex, Ethnicity, Socio-economic Status, Citizenship Status.

As part of developing the structured interview protocol, a relational template was developed. The template is an extension of Table 1, and demonstrates the connections among the APS research question categories, operationalization of research questions in the PIE Survey (in terms of the PIE variables presented in Table 2), and operationalization of research questions in the Structured Interview Protocol. This format was created for each APS research question category. The template outlines how the structured interview added richness to the survey while independently generating new information.

A section of the template is provided in Table 3 in order to illustrate its utility. The PIE Survey Variables 4 and 7 are determined to be associated with APS research questions under Skills. One operationalization of those PIE Variables in the interview protocol is to probe if the subject has had any experiences inside or outside of his/her classes that enabled him/her to solve problems.

Table 3. *Example of the relationship among the fundamental APS Research Questions related to Skills, PIE Survey Variables, and Interview Questions.*

APS Research Question Category	Associated PIE Survey Variables	Operationalization in Interview Protocol
SKILLS	Variable 4. Confidence in Engineering Knowledge and Skills Variable 7. Ability to Solve Open-Ended Problems	Have you had any experiences inside or outside of your classes that have enabled you to solve problems? Please describe those experiences.

This template will be used as a framework to relate and compare the responses to the PIE Survey and the Structured Interviews.

IV. Internal Consistency of Survey Variables

Participants

The Cohort 1 survey participants consisted of forty students from each of the four institutions. As noted above, these students entered into their respective institutions in Fall 2003 and were selected for participation based on their indicated interest in studying engineering. Based on responses to demographic questions asked in the Winter 2004 survey, the students in Cohort 1 are not married (100%), the majority are U.S. citizens (83%), and have a modal age of 19. By sex and ethnicity, the cohort is 61% male and 39% female; 42% White/Caucasian, 23%

Black/African-American, 18% Asian/Asian-American/Native Hawaiian/Pacific Islander, 3% Mexican American/Chicano/Latino, and 14% Other/Multiracial.

Variable Development

Questions were developed to assess indicators of persistence in engineering. The Winter 2004 survey contained 147 items and the Spring 2004 survey contained 137 items. For the Fall 2004 survey, both the variables and the items from the Spring 2004 survey were significantly revised, resulting in 115 items. The response choices for several of the scales were also revised to improve the interpretability of results. The Cronbach's Alpha scores resulting from the internal consistency reliability analyses were used to refine the Fall 2004 survey. A detailed review of the variables in relation to relevant literature resulted in the rewriting of scales and items in order to make the questions more consistent with the variables.

Using data from the Spring and Fall 2004 surveys, we performed reliability analyses which yielded coefficient alphas ranging from .49 to .79 for the Spring 2004 survey and .49 to .80 for the Fall 2004 survey. Table 4 presents the coefficient alphas for the variables from both the Fall 2004 and Spring 2004 surveys. The corrected item-total correlations for the Fall 2004 survey represents the correlation of the individual item with the sum of all other items. Standard scores for each of the individual items (where each item score was transformed into a "z-score" which has a mean of 0 and a standard deviation of 1) were created prior to creating the summed variable score.

Table 4. *Fall 2004 and Spring 2004 Survey Scale Items, Internal Consistency Reliabilities, and Item-Total Correlations*

Variable and Item Content	**Fall 04 Item-Total Correlation**	**Fall 04 Alpha**	**Spring 04 Alpha**
2a: Motivation (financial)		.80	.79
Engineers are well paid.[1]	.77		
Engineers make more money than most other professionals.[1]	.77		
An engineering degree will guarantee me a job when I graduate.[1]	.43		
2b. Motivation (Family Influence)		.74	.47
My parents would disapprove if I chose a major other than engineering.[2]	.59		
My parents want me to be an engineer.[1]	.59		
2c. Motivation (Belief that Engineering has a positive impact on solving the world's problems)		.73	.49
Technology plays an important role in solving society's problems.[1]	.58		
Engineers have contributed greatly to fixing problems in the world.[1]	.58		
2d. Motivation (high School Teacher/Mentor Influence)		---	.75
A high school teacher/advisor encouraged and/or inspired me to study engineering.			
One or more of my favorite high school teachers were math/science teachers.			

Variable and Item Content	Fall 04 Item-Total Correlation	Fall 04 Alpha	Spring 04 Alpha
I had one or more high school math/science teachers who seemed genuinely excited about math/science.			
2e. Motivation (Mentor Influence)		.69	---
A faculty member, academic advisor, teaching assistant or other university affiliated person has encouraged and/or inspired me to study engineering.	.53		
A non-university affiliated mentor has encouraged and/or inspired me to study engineering.	.53		
3. Interpersonal Confidence		.71	.74
Self confidence (social)[5]	.54		
Self understanding[6]	.35		
Leadership ability[6]	.54		
Public speaking ability[6]	.55		
4a. Confidence in Engineering Knowledge and Skills (Technical)		.80	.76
Math ability	.67		
Science ability	.69		
Ability to apply math and science principles in solving real world problems	.67		
Computer skills	.37		
Critical thinking skills	.52		
4b. Confidence in Engineering Knowledge & Skills (Professional)		.70	.49
Communication skills	.49		
Ability to perform in teams	.53		
Business ability	.53		
5a. Perceived Importance of Engineering Knowledge & Skills (Technical)		.71	.72
Math ability	.60		
Science ability	.67		
Ability to apply math and science principles in solving real world problems	.33		
5b. Perceived Importance of Engineering Knowledge & Skills (Professional)		.70	.66
Communication skills	.53		
Business ability	.46		
Ability to perform in teams	.54		
6. Knowledge of the Engineering Profession		.59	.29
How much exposure have you had to a commercial engineering environment as a visitor or a professional?	.42		
I am familiar with what a practicing engineer does.	.42		
7. Ability to Solve Open-Ended Problems		.63	.57
Creative thinking is one of my strengths.[1]	.46		
I am skilled at solving problems that can have multiple solutions.	.46		
8. Opportunity to Solve Open-Ended Problems in Courses		.66	---
Frequency: Took courses which required your	.45		

Variable and Item Content	Fall 04 Item-Total Correlation	Fall 04 Alpha	Spring 04 Alpha
engagement in individual and/or group projects			
Since entering college, what percentage of your classes used the following teaching methods? Individual Projects	.40		
Team Projects	.54		
9. Exposure to Project-Based Learning Methods		.69	---
To what extent have your courses required your engagement in individual and/or group projects?	.48		
Frequency: Took courses which required your engagement in individual and/or group projects	.42		
Since September, what percentage of your classes used the following teaching methods? Individual Projects	.39		
Team Projects	.59		
10a.Interaction with Faculty (Frequency)		.49	.61
Faculty during office hours[5]	.32		
Faculty outside of class or office hours[5]	.32		
10b.Interaction with Faculty (Satisfaction)		.55	.67
Quality of instruction by faculty[4]	.37		
Availability of faculty	.37		
11a.Interaction with Teaching Assistants (Frequency)		.61	.73
TAs during office hours[5]	.43		
TAs outside of class or office hours[6]	.43		
11b.Interaction with Teaching Assistants (Satisfaction)		.68	.79
Quality of instruction by teaching assistants[4]	.52		
Availability of TAs	.52		
12. Satisfaction with Academic Facilities and Services		.80	.72
Computer facilities[5]	.50		
Libraries[5]	.66		
Classrooms[5]	.55		
Tutoring[5]	.55		
Academic advising[6]	.50		
Laboratories	.59		
14a. Academic Disengagement (Non-Engineering Related)		.71	---
Skipped non-engineering related class[6]	.35		
Came late to non-engineering related class[6]	.34		
Turned in non-engineering related assignments that did not reflect your best work[6]	.34		
Turned in non-engineering related assignments late[6]	.20		
Thought non-engineering related classes are boring	.22		
14b .Academic Disengagement (Engineering Related)		.61	.68
Skipped engineering related class[6]	.30		
Came late to engineering related class[6]	.50		
Turned in engineering related assignments that did not reflect your best work[6]	.33		
Turned in engineering related assignments late[6]	.40		
Thought engineering related classes are boring	.28		
15. Extra-Curricular Fulfillment		.79	---
Some people desire to be involved in non-engineering	.65		

Variable and Item Content	Fall 04 Item-Total Correlation	Fall 04 Alpha	Spring 04 Alpha
activities on or off campus, such as hobbies, civic or church organizations, campus publications, student government, social fraternity or sorority, sports, etc. How important is it for you to be involved in these kinds of activities?			
How often are you involved in the kinds of activities described above?	.65		
16. Curriculum Overload		.75	.69
How well are you meeting the workload demands of your coursework?	.43		
How stressed do you feel in your coursework right now?	.65		
Thinking about your college experience this year, please comment on the following: Course load (amount of course material being covered)	.54		
Course pace (the pace at which the course material is being covered)	.53		
Balance between social and academic life	.42		
18a.Work Style (Personal-Collaborative)			
I prefer studying in a group to studying by myself.[2]	.48	.57	.68
I prefer working as part of a team to working alone.	.33		
I get along well with others in study situations. [6]	.30		
Frequency: Participated in a peer study group.	.31		
18b.Work Style (Personal-Competitive)		.61	.41
I strive to get higher grades than my classmates.	.44		
I am a competitive person.	.44		
19a.Work Style (Institution-Collaborative)		.63	.50
Frequency: Took courses which required your engagement in individual and/or group projects	.31		
To what extent have your courses required your engagement in individual and/or group projects?	.40		
The educational institution I am attending promotes collaborative work.	.47		
I have easy access to work spaces where I can participate in peer study/discussion sessions with my fellow students.	.33		
I am encouraged by my instructors to initiate or participate in peer study sessions with my fellow students.	.38		
19b.Work Style (Institution-Competitive)		.61	.35
The educational institution I am attending promotes competitive work.	.43		
My instructors often remind students that they need to do better than other students to obtain high grades.	.43		

[1] Borrowed from the Pittsburgh survey
[2] Borrowed from the Pittsburgh survey, and modified slightly
[3] Borrowed from the CIRP survey
[4] Borrowed from the CIRP survey, and modified slightly
[5] Borrowed from the YFYC 2003 survey
[6] Borrowed from the YFYC 2003 survey, and modified slightly

Generally speaking, Cronbach's alphas of .60 and higher are considered acceptable levels of internal consistency. However, this is an arbitrary threshold, and after consulting with experts in educational measurement, we decided to aim for a higher standard of an alpha value of .70 or above. 13 of the 27 PIE Survey variables listed in Table-4 currently meet the minimum .70 alpha value. Of the other 14 variables, 4 are between .65 and .70, 6 are between .60 and .65, and 4 are below .60.

The Cronbach's alpha scores for the variables from the Fall 2004 survey yielded stronger evidence for internal consistency on 13 of the 21 PIE variables compared to the Spring 2004 survey variables (21 of the 27 PIE variables were included *both* in the Spring and the Fall administrations of the survey). The remaining alpha scores indicated little change or a slight decrease. This may be attributed to continuing modifications made in deciding which items to include under each variable. Also, the composition of the variables is slightly different from the Spring 2004 survey to the Fall 2004 survey since several items were added or deleted according to variable and survey refinements. However, the conceptual rationale behind each PIE Survey Variable as described in Table 2 remained the same throughout each of the surveys.

We plan to continue to use the data collected from the three administrations of the PIE survey to review and revise the variables and their respective items, particularly those with low internal consistency scores for future surveys. At the end of Cohort 1 data collection, variables with a Cronbach's alpha value lower than .65 will be removed from the instrument, and will not be considered in future analysis.

V. Conclusions

In this paper, the development process of the PIE Survey and the resulting instrument were presented. The data suggest that majority of survey variables are internally consistent. Conceptual validation of the survey variables will be undertaken once the longitudinal data collection of Cohort 1 of the APS is completed, and the survey data are analyzed in conjunction with the structured interview and ethnographic data.

Contributions of the research presented in this paper to engineering education research are:

1. The identification of a set of key variables characterizing core issues related to retention in engineering education today in the US, and the synthesis of those variables in a survey instrument. The resulting Persistence in Engineering Survey is based on the literature, comprehensive, and responsive to new insights and variables as they emerge from the APS.
2. A dynamic survey validation process that draws upon itself as well as other data sources within the APS for continued evolution (as indicated by the improvement in the internal consistency results over time). This process trades off some of the ability to gather longitudinal data for enhanced precision and interpretability. The tradeoff is acceptable since the Cohort 1 instrument is meant to serve as a pilot for the Cohort 3 instrument.
3. The formulation of a knowledge base which can inform and enrich the structured interview and ethnographic data sets within the study. This forms the basis of a mix-methods approach, in which key issues can be identified and explored as they arise.

Acknowledgements

This material is based on work supported by the National Science Foundation under Grant No. ESI-0227558, which funds the Center for the Advancement of Engineering Education (CAEE). We would like to thank Sheri Sheppard, Cynthia Atman, Lorraine Fleming, Reed Stevens, Ruth Streveler, Larry Leifer, Kevin O'Connor, George Toye, and Robin Adams for contributing to the development of the PIE Survey.

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